NITRD Strategic Plan
White Paper Submission

This note will argue that a major focus of NITRD strategy over the next five years should be on **Principles of Embedded Software**.

Software controls an enormous range of devices, ranging from safety-critical systems such as anti-lock braking systems in automobiles, cardiac pacemakers, and aviation flight-control; to systems with national defense and security implications such as missile guidance and command and control; to consumer devices such as cell phones and microwave ovens. The importance of such embedded software truly amounts to a silent revolution in device design; new features are routinely implemented using off-the-shelf sensors, actuators and microprocessors, with the specific desired behavior captured in source code. This new control-engineering paradigm has opened tremendous opportunities for great improvements in existing devices such as cars; indeed, widely quoted estimates from General Motors executives estimate that 90% of new feature content, and consequently profits, in automobiles will be software-driven. Embedded software has also enabled the development of devices, such as cell phones, that would not have been possible otherwise.

It is widely reported in the trade press that over 98% of new microprocessors are used in embedded applications: all of these microprocessors run embedded software. Already, however, shortages in the talent needed to develop this software can be observed, and are indeed driving the use of off-shoring as a stop-gap measure. Without revolutionary advances in the efficiency with which such software is developed, verified, certified and deployed, the pace of innovation in devices will necessarily slow, and our country's competiveness and security even threatened.

The European Union faces similar pressures in its device-oriented industries and has mounted a high-profile series of research initiatives, variously called Artemis / Artist, with a total 10-year budget of over €1.5bn, aimed at improving embedded-system design practices. The initiatives combine basic and applied research projects conducted by conglomerations of university, government and industry researchers. It is vitally important that the US also invest in the area of embedded systems and software in order to give its industrial base the scientific advances it needs to continue to innovate and compete.

By its very nature, embedded software is multi-disciplinary. Developing it requires input not only from software experts but also from control and system engineers with deep knowledge of the device domain (medical, automotive, aerospace, etc.), with their differing environmental assumptions and regulatory regimes. Advancing the state of the art in embedded software development practices will therefore require effective multi-agency collaborations within US Federal research and regulatory agencies. For example, medical devices represent an important societal good as well as a significant market niche for US companies; of special-interest are high value-added products such as radiological equipment, implanted cardiac

devices, and infusion pumps. Software currently accounts for a substantial portion of the development and certification costs of such equipment. New technologies for software design and verification would help, but would require support not only from basic-science agencies such as the NSF and NIH but also others such as the FDA. Similarly, in the aerospace arena, regulatory agencies such as the FAA should be involved in the support of embedded-software research that would also be funded by NASA, DARPA and the Air Force. An effective model would involve the shouldering of research costs by the research agencies, with the regulatory agencies providing capabilities for evaluation and input to technology development. This model is being used with some success by Fraunhofer via an NSF-funded project on medical-device software being conducted with input from the FDA, and expanding this model appropriately would offer significant avenues not only for research advances but for evaluation and future commercialization.